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Effect of Crushed Clay Brick as Partial Replacement of Fine Aggregate in Concrete

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ABSTRACT

The reuse of construction and demolition wastes, especially crushed clay bricks (CCB), represents a major contribution to the environment. Due to the nature of clay bricks, it can be considered as source of fine and coarse aggregate to produce structural concrete. This research has been conducted with the objectives of highlighting the effect of crushed clay brick as partial replacement of fine aggregate in concrete. Compressive strength of concrete made by different partial replacement of fine aggregates were evaluated on (0%,15%, 25%, 30%, 50%, and 75%). To achieve the objectives of this study, the laboratory tests have been performed. The strength of gravels has been investigated by Los Angles Abrasion test according to ASTMC 131. Sieve analysis was performed to determine the particle size distribution. The consistency and fineness test of Cimerwa cement was conducted and results of fineness of cement was 9.165%. Initial setting time was 98 minutes and final setting time was 256 minutes. The compressive strength of concrete was performed and the results at age of 28 days were 31.81Mpa, 29.38Mpa, 27.45Mpa, 24.86Mpa, 17.91Mpa and 15.84Mpa respectively. The percentage reductions for (15%, 25%, 30%, 50% and 75%) was 7.63%, 13.70%, 21.84%, 43.69% and 50.20% respectively. According to IS 456 specified minimum compressive strength of concrete after 28 days of curing is $25N/mm^2$ for M25 grade of concrete, with the partial replacement of 20%, the resulted compressive strength is 27.45 Mpa.

Keywords: Compressive strength; Partial replacement; Final setting; Consistency; Fineness.

1. General Introduction

1.1. Introduction

Concrete is far the most widely used construction material nowadays, concrete has attained the status of a major building in all branches of modern construction (Rakietal, 2010). Concrete is the second most consumed material in the world after water (Naville, 2005). This growth in construction industry in past decade has increased the demand for concrete and its constituent material. Concrete is mainly made up of cement, coarse aggregate and fine aggregate. A high-quality control is obtained on cement because of decades of experience gained in manufacturing cement. Coarse aggregates are generally extracted by stripping and blasting, crushed, washed and graded to requirement. Bricks have long been among the most important materials used in construction industry. The use of dried clay bricks was recorded as far back as 8000 BC, while fired clay bricks were used as early as 4500 BC (Arshad, 2014) . Clay bricks are produced in large quantities throughout the world and the demand for them is expected to continuously rise. In spite of the advanced production technology used nowadays, a significant proportion of bricks are rejected due to being out of standard: these units may be broken, distorted, damaged, underburned or overburned. Research on crushed clay brick has generally been undertaken on their effects as finely ground materials to replace cement in mortar and concrete due to their pozzolana city (Wild, 1999).

A good quality control is hence maintained in manufacturing of coarse aggregates. However, due to the geology of the area, there is high possibility that excavated or stripped rocks may contain clayey matrix. It possesses a possibility that clay can get carried away with fine or coarse aggregate even after washing. This will lead to addition of clay fines in concrete. Clay fines, having clay minerals are high water absorbent and have high shrinkage ability. Apart from affecting strength properties of concrete, they increase the shrinkage of concrete

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(Naville A. , 2005). This reduces the durability of concrete and the life of structure. Fines should not be present in excessive quantities because, owing to their fineness and therefore large surface area, fines increase the amount of water necessary to wet all the particles in the mix (Cramer, 2011). The strength of concrete depends upon the components such as aggregate, quality of Cement, water-cement ratio and workability, normal consistency of mix, proportion and age of curing of concrete. New building materials were used to accelerate the Construction work, in which the mixture plays an important role in characteristics of Concrete. The growth in various types of industries together with population growth has Resulted in the enormous increase in production of various types of industrial waste material such as crushed clay brick, foundry sand, blast furnace slag, fly ash, steel slag, scrap tires, waste plastic, broken glass (Gambhir, 2013).

This experimental study has focused on using crushed clay brick as partial replacement of fine aggregate contained in concrete, with an aim of coming up with acceptable concrete mixture that can be used in building construction particularly partitions and ensuring that properties of concrete such as compressive strength and workability are maintained within the standard limits. This study is conducted with purpose of assessing the impact of the crushed clay brick used as a partial replacement of fine aggregate in concrete and assess the strength and workability characteristics. Because Rwanda is currently passing a very successful period of development in many fields including brick burning process. Therefore, there is need to explore alternative building materials from construction waste material that can be recycled. Crushed clay is often discarded as waste after defined as useless but it can be recycled. The cost of fine aggregate is increased a day by day so replacing them partially by crushed clay bricks will reduce the cost of concrete. So that’s why we need to assess the strength and workability characteristics of this concrete.

1.2. Overview on previous studies

During the last decades, it was observed that the wastes from construction and demolition sectors constitute large volume and this volume increased year after year. Demolition waste was about 180 million tons in EU countries per year (Pladerer, 2006). In addition, the industry of brick manufacturing, which produce sizable amount of rejected fired- brick and these units may be broken and cause environmental pollution (AR, 2006).Therefore, many researchers studied the effect of using these local wastes in production of concrete to reduce their harmful effect and to get concrete with good characteristics with reduced cost. Researchers started to study the possibility for recycling wastes from construction demolishing which represented in crushed clay brick to produce light weight (LW) concrete. It is reported that fine CCB obtained from waste products (e.g. demolished masonry) possess Pozzolanic characteristics and can be used as supplementary cementitious materials in concrete (Wild S, 1998). Recycled brick aggregates recovered from demolished masonry structures can be utilized in the manufacture of new concrete mixtures.

In order to ensure a sustainable waste management, it is necessary to predict its properties and to specify its utilization. Water absorption and void content of crushed-brick aggregate were several times higher than those of crushed stone aggregate (Khaloo, 1995).Generally, concrete with recycled brick as an aggregate has a relatively lower strength than a normal aggregate concrete. This characteristic can be attributed to the higher water

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absorption of recycled crushed brick aggregate compared to natural aggregate. Increasing of the rate of substitution natural fine aggregates with brick decreases the compressive strength. At 28 days of curing, the decreasing in compressive strength was in the order of 10-35 % for the recycled coarse aggregates concrete in comparison with an ordinary concrete (Dabieb, 2008). However, the strength of the concrete with recycled by crushed brick as an aggregate depends on the strength of the original brick. For instance, the use of crushed brick aggregates, obtained from brick with higher initial strength, may exceed the compressive strengths reached using granite aggregate, even allowing for the production of high strength concrete (Khalaf, 2006) . Generally, it is possible to estimate the strength of the concrete with the brick as the coarse aggregate from the strength of the original brick (Khalaf,F.M., 2006). Recycled crushed clay brick is one of the best aggregates for concrete that may have to resist fire, and it performs much better than similar concrete containing granite aggregate (Khalaf, 2004). Most current researches use crushed clay brick as a coarse and/or fine aggregate in conventional concrete. Few researches reported that crushed brick powder could be used as partial replacement of fine aggregate in concrete. Recycling crushed clay brick wastes needs more researches to make the use of these wastes. Producing aerated concrete with crushed clay brick as an alternative to fine aggregate will present solution for these recyclable wastes (Diniya David, 2017).

According to (Kenai, 2008), Farid Debbie and Said Kenai (2008), the use of course and fine crushed bricks as aggregate in concrete was studied. This paper examines the possibility of using crushed brick as coarse and fine aggregate for a new concrete. Either natural Sand, coarse aggregates or both were partially replaced (25, 50,75 and 100%) with crushed brick aggregates.

Compressive and flexural Strengths up to 90 days of age were compared with those of concrete made with natural aggregates. Porosity, water absorption, water Permeability and shrinkage were also measured. The test results indicate that it is possible to manufacture concrete containing crushed Bricks (coarse and fine) with characteristics similar to those of natural aggregates concrete provided that the percentage of recycled aggregates Is limited to 25% and 50% for the coarse and fine aggregates, respectively. When crushed clay brick powder is added the compressive strength reduces first and then increase by 25% of addition, after that the strength is reducing (Diniya David, 2017). The water-cement ratios slightly increased as the percentages replacement increased; the higher crushed brick substitution the higher was the water-cement ratio. This could be due to the porosity of the fired clay brick that required higher water content compared to natural aggregate in all mixes. Optimum compressive and flexural strength were obtained at 40% replacement of coarse aggregates after 28 days of curing period (Ummi Kalsum, 2008). Both the compressive strength and the flexural strength decreased with the increasing of the replacement percent of recycled clay brick and the impermeability of concrete decreased with the increasing of the replacement percent of recycled clay brick. But the permeability of concrete with the water to cement ratio of 0.35 was still kept at “Low” level when the replacement percent was less than or equal to 75%. (Wencui Yang, 2020).

According to the literature review we were used the following mix ratio of 1:2:3 in order to check the behavior of concrete at 7 days and 28 days. Where the proportions of sand are replaced partially by crushed aggregates from 0%, 15%, 25%, 30%, 50%, 75% in order to check which proportion can be used in construction works like concrete of compressive strength of 20 Mpa and 25Mpa.

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2. Materials and methods

2.1. Materials collection

The materials used such as coarse aggregates, fine aggregates, crushed clay brick, cement and water to carry out test or experiments were collected from different locations. Cement is the binder material in concrete, in this research Portland pozzolana cement with the characteristic compressive strength of 32.5 N/mm^2 was used. Coarse aggregate used in this study were collected from Bwakira stone quarry which is located at Nyanza district in the southern province, it was normal sized of 16 mm to 25 mm while fine aggregate also collected river sand sourced from Bwakira and crushed brick is taken in Huye district.

2.2. Material testing

The different tests are carried out such as moisture content, sand equivalent test, sieve analysis, Los Angeles abrasion for aggregates, fineness, consistency and setting time for cement, slump test and compressive strength for concrete are explained in this section.

Figure 1. Concrete ingredients batching and broken bricks

3. Presentation and Analysis Results

3.1. Fine aggregate tests

3.1.1. Moisture content of sand (MC)

The moisture content of sand was determined from this section. The number that represents the amount of water in sand used was 24% as represented in (table) below. This amount of water in sand could affect both weight of sand and the amount of water needed in concrete.

Table 1. Moisture content of the sand

S. No.	Particular	Weight (g)
1	Weight of saturated fine aggregate (W1)	1000
2	Weight after oven drying (W2)	976
MC= (1000-976) *100/100 = 24%		

3.1.2. Sand equivalent

The sand equivalent was expressed as a ratio of the height of clay over the height of sand after a 10 minutes soaking time. Higher sand equivalent value indicates "cleaner" (less fine dust or clay materials) aggregate. Typical sand equivalent values range from 30% to 90%.

Table 2. Sand equivalent results

Tested samples	Sample 1	Sample 2	Sample 3
Sand reading after irrigation and sedimentation	8.8	8.5	8.2
Clay reading after irrigation and sedimentation (H2)	6.9	6.6	6.3
Sand equivalent $= \frac{H2}{H1}$*100	78.4	77.64	76.83
Sand equivalent	77.62%		

The sand equivalent for a good quality of sand should be above 60% since the results to greater than 60% as shown in (Table 2) thus the sand used was good quality hence required to give the best results as far as the compressive strength is concerned.

3.1.3. Sieve analysis

(a) Sieve analysis of fine aggregate

The initial weight was 3000g and final weight was 2972.5g. And according to IS383. When the percentage of passing for sieves 10, 475, 236, 118, 0.600, 0.300 and 0.150 is 100. 90-100, 75-100, 55-90, 35-59, 8-30 and 0-10 the fine aggregate is a curve sand of grade II. The fine aggregate used was in grade II as the percentage of passing for the sieves as shown in (figure 2) indicate that the sand used was the coarse sand.

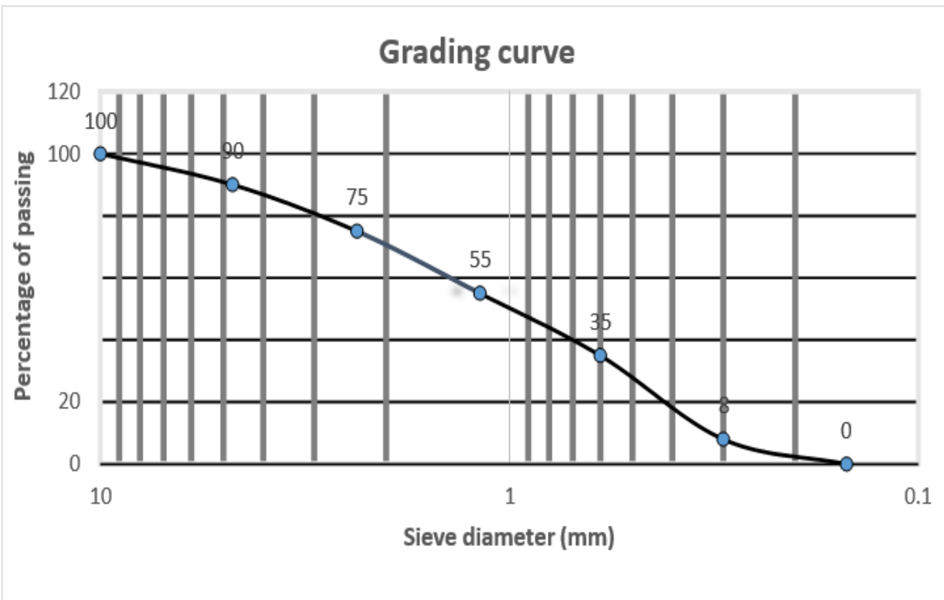

Figure 2. Particle size distribution curve of aggregate

(b) Sieve analysis of crushed clay brick

The initial weight was 3000g and final weight was 2972.5g. And according to IS383, when the percentage of passing for sieves 10, 4.75, 2.36, 1.18, 0.600, 0.300 and 0.150 is 100.90-100, 75-100, 55-90, 35-59, 8-30 and 0-10 respectively the sample is a coarse crushed clay brick of grade II. The crushed clay brick aggregate used was in grade II as the percentage of passing for the sieves shown in (figure) below that indicate the sand used was the coarse sand.

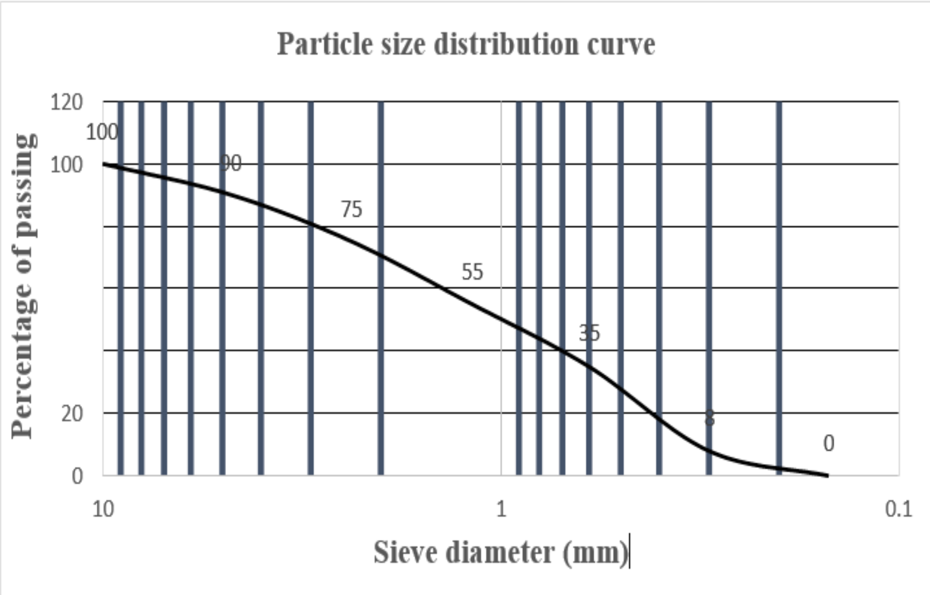

Figure 3. Particle size distribution curve of crushed clay brick

3.2. Coarse aggregate test

3.2.1. Los Angeles abrasion test (grade A)

Grade A was used to determine the resistance of coarse aggregate as shown in the (Table)below, Abrasion value = (5000-4103) * 100/5000= 17.93% and according to ASTM C131, the abrasion value of coarse value of coarse aggregate used in construction of concrete should not exceed 35% then the abrasion value result was 17.93% which is less than 35% so the aggregate that has been used was good and can't affect the concrete properties

Table 3. Los Abrasion value determination

Sieve diameter	Quantity (g)	Number of steel balls used
16mm	3000	12
20mm	2000	
Total weight (W1)	5000	
Retained (W1)	4103.5	

3.3. Cement tests results

The fineness was determined and fineness values are presented. According to IS code specification fineness of cement should not be more than 10% that means the concrete cement mix has good cohesiveness and it cannot

affect the concrete. The fineness of cement is 9.33%. Consistency which was permit vicat plunger to penetrate to a point 5 mm from the bottom of the vicat mould was 32% the water which was required to produce a cement paste of standard consistency was 128g and the results is good so cannot affect the workability of concrete for the standard or normal consistency for Portland cement which range from 25 to 35% of cement sample as per IS: 5513:1996.

3.4. Concrete test results

3.4.1. Workability concrete test

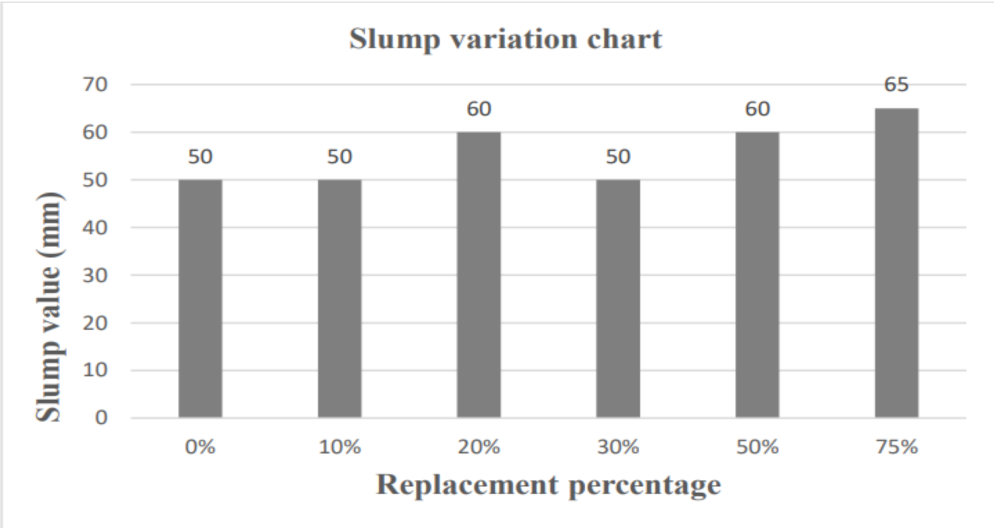

Figure 4. Slump variation results

3.4.2. Compressive strength test

After conducting compressive strength test at age of 28 days results showed that optimum possible partial replacement was 20% that gives 17.13 Mpa as shown in figure below then a minimum compressive at age of 7 days should not be less than 17 Mpa according to IS 456.

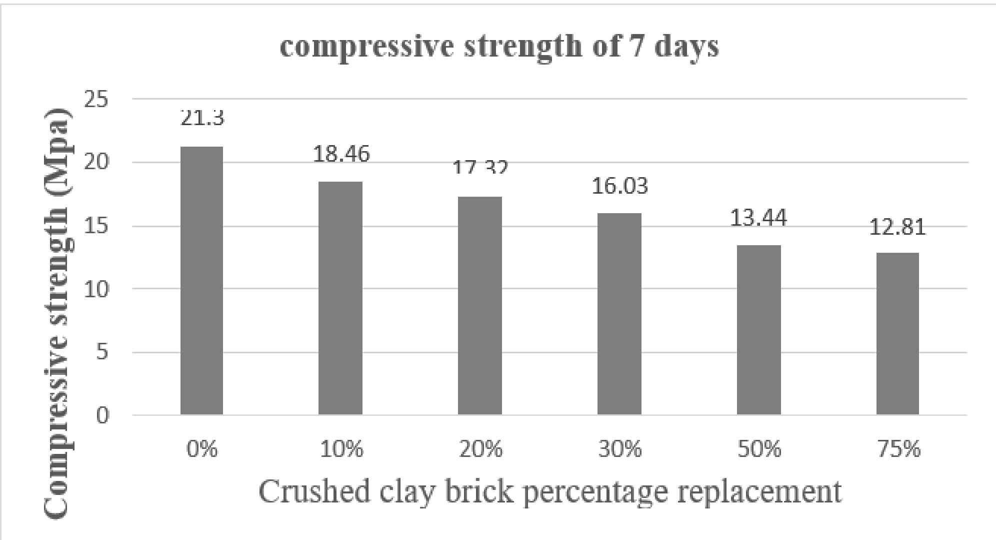

Figure 5. Compressive strength at age of 7 days

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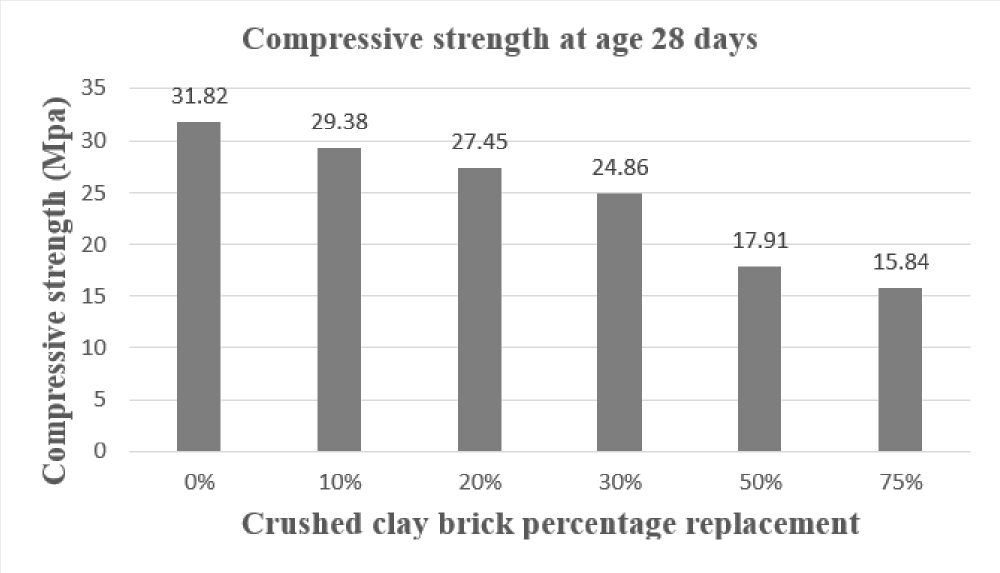

Figure 6. Compressive strength at age of 28 days

The crushed clay brick has the great impact to reduce compressive strength of concrete after curing as shown in figure below indicate the reduction of compressive strength at age of 28 days. Concrete have to be replaced until optimum replacement of 20% for M25 grade of concrete as per IS 456 specified minimum compressive strength of $25N/mm^2$ for M25 grade of concrete.

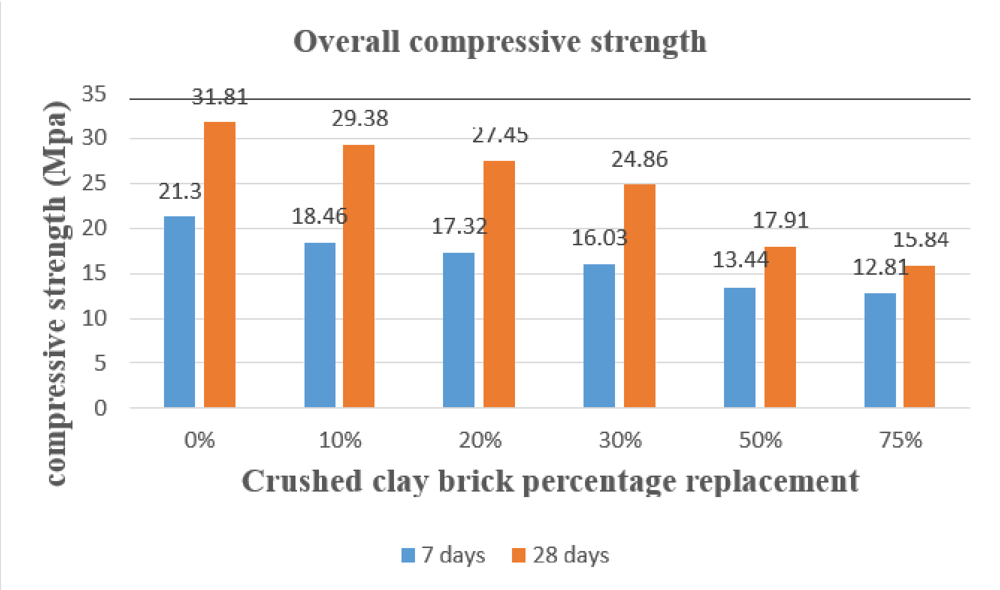

Figure 7. Overall compressive strength

4. Discussion on Results

After conducting compressive strength test results showed that at age of 28 days the percentage reduction in strength at different partial replacement (10%, 15%, 25%, 50% and 75%) were 7.63%, 13.70%, 21.84%, 43.69% and 50.20% respectively. Compressive strength of control specimen concrete and partial replacement (0%, 15%, 25%, 50% and 75%) were 31.76Mpa, 28.7Mpa, 27.28Mpa, 24.46Mpa, 17.82Mpa and 15.73Mpa respectively

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as shown in figure 7 above and therefore 15% should be selected to use in construction. According to IS 456 specified minimum compressive strength of concrete after 28 days of curing is 25N/mm2 for M25 grade of concrete.

5. Conclusion

In this research, the effects of the partial replacement of fine aggregate with crushed clay brick on the workability and compressive strength of concrete were investigated based on the results of the control specimen (concrete without crushed clay bricks) and the concrete made by fine aggregate partially replaced by crushed clay brick at (10%, 15%, 25%, 50%, 75%) the following conclusion were drawn. Sieve analysis of crushed clay brick sample result showed that the sand used was the coarse sand of grade II which is good to be used in construction. Minimum decrease in compressive strength at 28 days occurred at the replacement ratio of 10% was 9.63% compared with control specimen of 31.81Mpa while the maximum decrease in compressive strength at 28 days at replacement ratio of 75% was 50% compared with control specimen. For M25 grade of concrete, according to IS 456 specified that the minimum compressive strength of concrete after 28 days of curing is 25N/mm^2 for M25 grade of concrete, replacement for M25 grade of concrete are 20% of 27.45Mpa. For M20 grade of concrete replacement are 30% of 24.86Mpa and for M15 grade of concrete replacement are 75% of 15.84Mpa.

Declarations

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Competing Interests

The authors declare no competing financial, professional and personal interests.

Consent for publication

We declare that we consented for the publication of this research work.

Availability of data and material

Authors are willing to share data and material according to the relevant needs.

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